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RECEPTION AND INVESTIGATION OF THE PROPERTIES OF RADIO
SIGNALS FROM SOVIET SPACE ROCKETS

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RECEPTION AND INVESTIGATION OF THE PROPERTIES OF RADIO SIGNALS FROM SOVIET SPACE ROCKETS

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This paper deals with the result of observations of the radio signals from the three Soviet space rockets, launched toward the moon in 1959. Some of the data are given in the table below.

Name	Purpose of Flight	Date of Launch	Transmitter Frequencies, Mcs
1st rocket	"Flyby"	January 2	19.993 and 183.600
2nd rocket	"Hard" landing	September 12	19.993; 39.986 and 183.600
3rd rocket	Orbit and photography the dark side	October 4	39.986 and 183.600

1. EQUIPMENT USED FOR SIMULTANEOUS RECEPTION AND REGISTRATION OF 20 AND 40 Mc SIGNALS

The short-wave transmitters placed in the instrument capsule of the 2nd Soviet rocket had a common quartz-stabilized master oscillator and multiple operating frequencies of 19.993 and 39.986 Mc. The transmitters operated in the telegraph mode, so that a break in transmission from either one initiated transmission from the other. Multiples of the transmitter operating frequencies were used in the design of the receiving equipment for simultaneous tuning to both frequencies.

The receiving section (block diagram shown in Fig. 1) has two channels, one at 20 Mc and the other at 40 Mc. The 20-Mc channel consists of an antenna 1 with antenna booster 3 and short-wave receiver 5. After the antenna booster 4 on the 40-Mc channel there is inserted a mixer 6 with local oscillator 7 lowering the frequency of the signal arriving at the input of short-wave receiver 8 to 3 Mc.

In order to eliminate the influence of the receiver tuning and frequency instability on the beat oscillators, reference frequency oscillations were introduced in the channels. Together with a signal and common detection, these produced beats of different (low) frequencies in the receivers. As a source of reference frequency oscillations, multiplier-modulators 22 and 23 were used. Oscillations of 2 Mc were applied onto the first grids of the tubes in these multipliers from the generator 21, which was crystal-stabilized in a passive thermostat, and a modulating voltage with frequency f_b was applied from generator 24

onto the third grids. The frequency spectrum in the anode circuit of the multiplier-modulators consisted of the components of the fundamental frequencies, through 2 Mc, and their side frequencies. In the 20-Mc channel the side frequencies deviated from the fundamental by $\pm f_b$, while in the 40-Mc channel,

the variation was twice this value, since the frequency of the modulating signal was previously doubled by the multiplier 25. When tuning to one signal from among all the signals, only the lower sideband components with frequencies $(20-f_b)$ and $(40-f_b)$ Mc were separated along with the signal. The frequency of

these sideband components varied exactly by a factor of 2.

When the tuning of the modulating frequency generator was varied, the frequency of the beats and of the reference signal in the 20-Mc channel were set at 1 kc, while in the 40-Mc channel the beat frequency was 2 kc. The receivers were tuned in such a manner that the signal was in the middle, while the reference oscillations were at the passband boundaries of the intermediate-frequency amplifiers of each receiver. Then the image channels lay outside the receiver passband.

The tuning accuracy was controlled by means of the oscilloscopes 26, 27 according to the Lissajous patterns formed at the receiver outputs by the beats and by the 1000-cps auxiliary voltage from the quartz oscillator 28. If the transmitter frequencies are in strictly multiple ratio, then, in exact tuning, standing-wave patterns are simultaneously observed on the oscilloscope screens: an ellipse for the 20-Mc channel, and a "figure-of-eight" for the 40-Mc channel.

The above described two-channel receiving system was particularly useful for the reception of weak signals with pronounced fading. Thus, if in one of the channels the signal was lost in the background noise, then it was possible to observe it in the other channel.

The beat envelopes at the receiver outputs were separated by the detectors 15 and 16 and recorded on paper tape by the automatic recorders 19 and 20. By varying the parameters of the integrating networks 17, 18, the time constant of the detectors could be changed over the range from 0.5 to 5 sec. In front of the detectors, band filters 13, 14, with variable passbands were connected. The passband of filter 13 in the 20-Mc channel could assume any

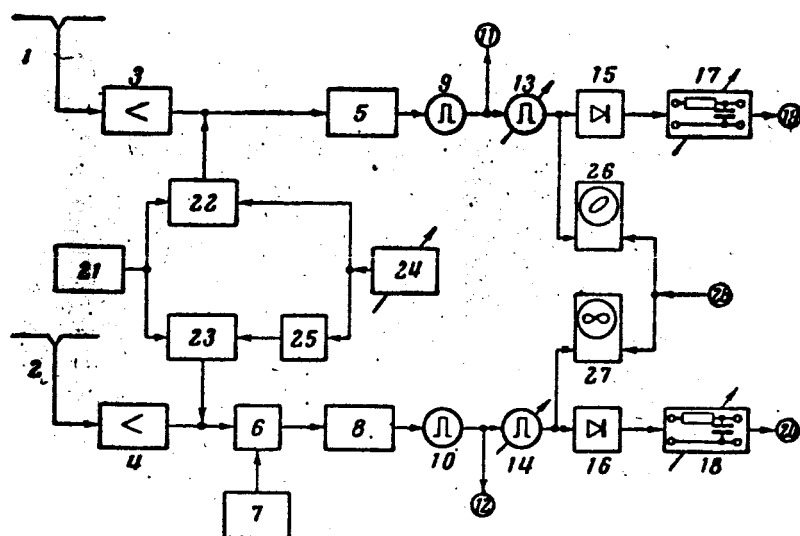


Fig. 1. Block diagram of equipment for simultaneous reception and registration of signals at 20 and 40 Mc

1, 2—"wave duct" antennas for 20 and 40 Mc, respectively; 3, 4—antenna amplifiers; 5—20 Mc receiver; 6, 7—mixer and beat oscillator ($f_b = 37$ Mc) in 40 Mc channel; 8—short-

wave receiver in 40 Mc channel; 9, 10—band filters for 1 and 2 kc, respectively; 11, 12—channel outputs to magnetic recorder; 13, 14—narrow-band filters (for 1 and 2 kc); 15, 16—detectors; 17, 18—integrating circuits; 19, 20—outputs to automatic-recorders; 21—2 Mc standard frequency generator; 22, 23—multiplier-modulators; 24—modulating frequency generator (8 kc); 25—modulating frequency doubler; 26, 27—control oscilloscopes; 28—1 kc auxiliary voltage

one of three values—50, 100 or 200 cps, while the passband of filter 14 in the 40-Mc channel took on values twice as great.

The signals in both channels were also recorded (from points 11 and 12) on magnetic tape. Apart from the 1- and 2-kc beats, a 300-cps range-marker signal from a quartz oscillator was also registered on magnetic tape. The origin of this signal corresponded precisely to a certain minute of astronomical time. In order to avoid crosstalk between the channels when both were combined, band filters 9 and 10 were set up at the receiver outputs. Partly modified versions of the same block diagram were used for the reception of signals from the 1st and 3rd rockets. Thus, for instance, in the case of the 3rd rocket,

a 20-Mc channel with a converter for reducing the signal frequency was used to receive the 183.6-Mc signals.

The general shape of the "wave duct" antennas used in the reception of signals from the space rockets is shown in Fig. 2. A two-tier, three-element antenna was used for the 20-Mc frequency and a ten-element one for the 40-Mc frequency, the latter having two independent channels for the reception of signals with mutually perpendicular polarization. The antennas are set up according to the azimuth and elevation. The gain of the 20-Mc antenna was 8 - 10, and that

of the 40-Mc antenna was about 20; the effective areas were 200 and 100 m², respectively.

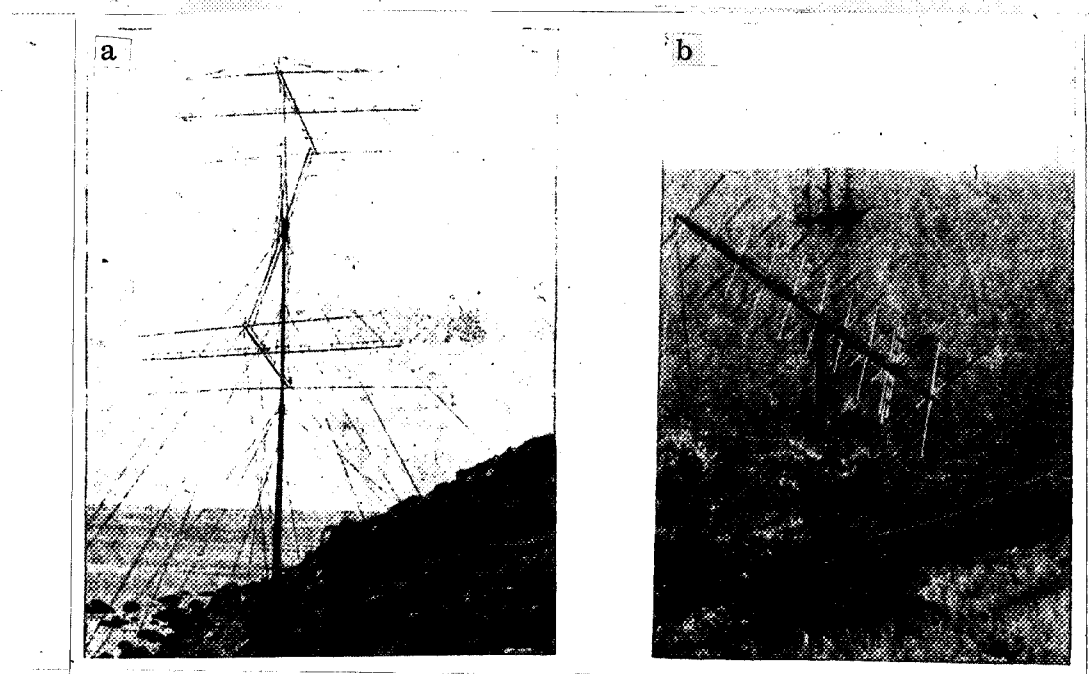


Fig. 2. Antennas used for reception of radio signals from the Soviet space rockets

a) 20 Mc; b) 40 Mc

The antenna amplifiers, used for compensating the losses in the feeders and for proving the receiver sensitivity, had noise factors of 3 - 5 in the 20-Mc channel and of about 2 in the 40-Mc channel. The real sensitivity of the receiving equipment was basically determined by the intensity of the space radio emission, whose effective temperature for the 40-Mc frequency amounts, as we know, to several thousands of degrees, and, at 20 Mc, may even reach several tens of thousands of degrees.

The operation of the entire assembly was repeatedly checked by comparing the signals from a transmitter on board the 3rd Soviet artificial earth satellite with the fundamental frequency (20.005 Mcs) and its second harmonic (40.010 Mc). Moreover, the signal level of the second harmonic exceeded the noise in the 100-cps band by a factor of 10 or more (voltage standpoint).

2. OBSERVATION OF RADIO SIGNALS FROM SOVIET COSMIC ROCKETS

The 20-Mc frequency reception began approximately 20 - 30 minutes after the separation of the payload capsule as it entered the lower lobe of the receiving-antenna radiation pattern. The oscillograms, which show signals from the 1st space rocket at a frequency of 20 Mc, receiver passband, 250 cps, are given in Fig. 3. These were recorded at 3:41 on January 3, 1959 when the capsule was 115,00 km from the earth. The oscillograms show the polarization fading in the signal caused by the rotation of the package and occurring at about 1 minute intervals.

The receiving antennas were set up on a steep seashore (see Fig. 2). Because the radiation pattern was fairly wide, both direct and reflected (from the water surface) beams were received. The strength of the signal increased or decreased as a function of phase difference between the two signals. The period of these fluctuations was a function of the height of the antenna above sea level and the rate of change of the incident angle of the signal, and was, on the average, 1 hour.

The termination of reception at 20 Mc occurred long before the capsule disappeared from the line of direct vision, and coincided with the time of sunrise. Before sunrise, the signal began to weaken, the noise received from antenna increased, and frequent fading occurred due to the peculiar properties of radio signal propagation in the ionosphere. At times, the signal was entirely lost in the noise, and then would briefly reappear, with greater strength, only to be lost again at sunrise in the noise from the remote radio stations whose night-broadcasting was not monitored. The 20-Mc reception of signals beyond the line of sight was not recorded.

At 5:50 when the 1st space rocket passed near the moon (maximum approach at 5:57), the signal from the 20-Mc transmitter died out rapidly, but gradually reappeared at about 6:15. The reception at 183.6 Mc continued during that time and no significant variation in signal level was observed. A loss of signal at 20 Mc occurred at 2-1/2 hours before sunrise and was not accompanied by the frequent fading which is characteristic for the change in the conditions of propagation in the ionosphere.

The reception of signals at 20 Mcs from the 2nd rocket commenced soon after sunset and was continued until the capsule passed beyond the zone of direct

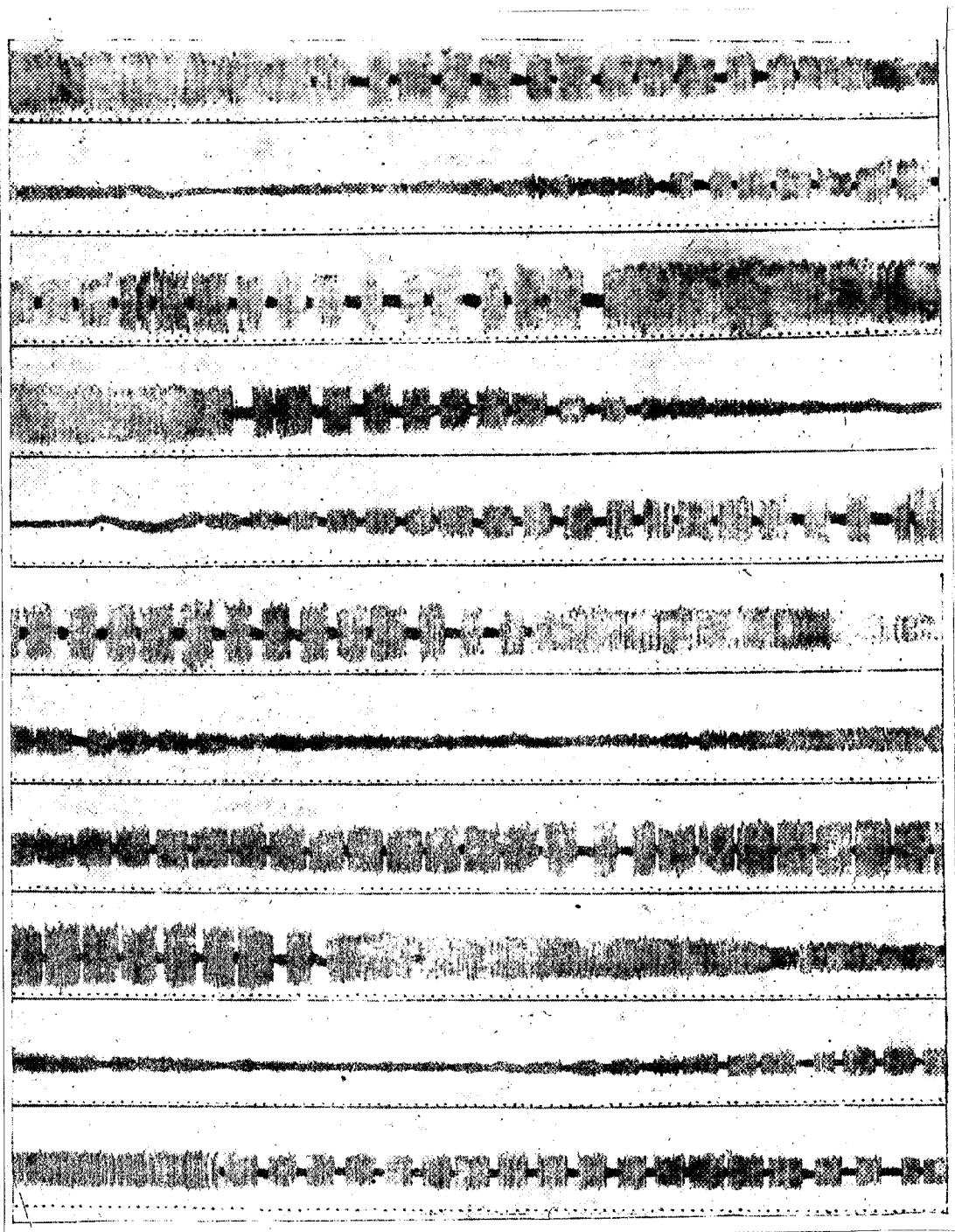


Fig. 3. Oscillograms of radio signals from the 1st Soviet space rocket
at 20 Mc (recorded on Jan. 3, 1959)

Points in the lower part of oscillograms—time pips 0.2 sec apart

vision. The nature of reception at 40 Mc was different. Weak signals from the 40 Mc transmitter were detected approximately 15 minutes before the ascent of the payload capsule. At times pronounced signal fading was observed for 20 - 30 seconds. Positive reception commenced approximately 1/2 hour after the ascent. The effect of the ionosphere on signal propagation was, at this frequency, considerably reduced. The signal levels before and after sunset were approximately identical.

3. "HARD" LANDING OF PAYLOAD CAPSULE OF THE 2ND SOVIET COSMIC ROCKET

The time at which the payload capsule of the 2nd cosmic rocket impacted the moon was fixed by the instant the signal transmission from the capsule was discontinued. Figure 4 shows the record of the 20-Mc signal during the last minutes before impact.

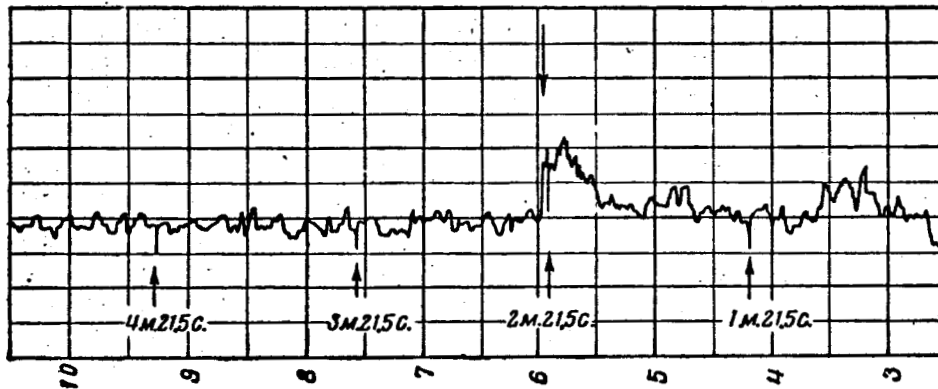


Fig. 4. Recording of radio signals from the 2nd Soviet space rocket at 20 Mc during last minutes before capsule impact on moon (9-14-59)

Arrow in upper part of figure marks time when signal disappeared (impact)

It can be seen from the above figure that before the landing the level of the 20-Mc signal increased considerably. The termination of reception corresponded to $0:02:23.5 \pm 0.25$ sec Moscow Time. Since the time of travel of a radio signal between the moon and earth is 1.25 sec, we calculated that impact occurred at $0:02:22.25 \pm 0.25$ sec Moscow Time on September 14, 1959. The same time was registered at the frequency of 183.6 Mcs [1].

Prior to impact, a Doppler variation in frequency was observed, caused by the change in radial velocity of the capsule induced by the gravitational field of the moon. The change in the receiving frequency of the 20-Mc transmitter during the last part of the travel of the capsule is shown in Fig. 5.

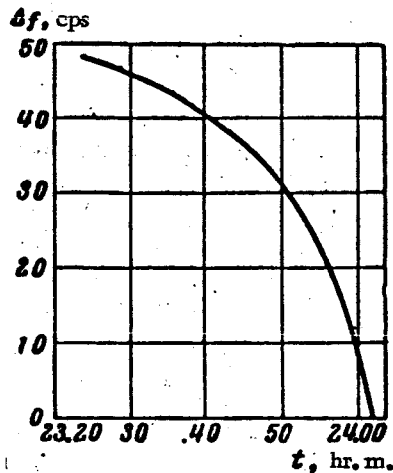


Fig. 5. Change in receiving frequency of 20 Mc transmitter during last part of travel of capsule of 2nd Soviet space rocket

Here the accuracy of frequency measurement was ± 1.5 cps. During the final hour, the frequency decreased by approximately 50 cps. This corresponded to an increase in radial velocity of the capsule of 750 m/sec.

4. SIGNAL FADING CAUSED BY ROTATION OF CAPSULE

The effect of fading of signals from the 1st Soviet cosmic rocket at 20 Mcs frequency as a result of rotation of the capsule can be seen on the oscillograms in Fig. 6. This fading was regular. It can be seen from the oscillograms that the period of fading both in the 1st (January 3) and second (January 4) series of observations was the same: 50 - 55 sec. Occasionally, sequence fading of different depth was observed, in which the average period between two consecutive events was preserved (on the right of Fig. 6a).

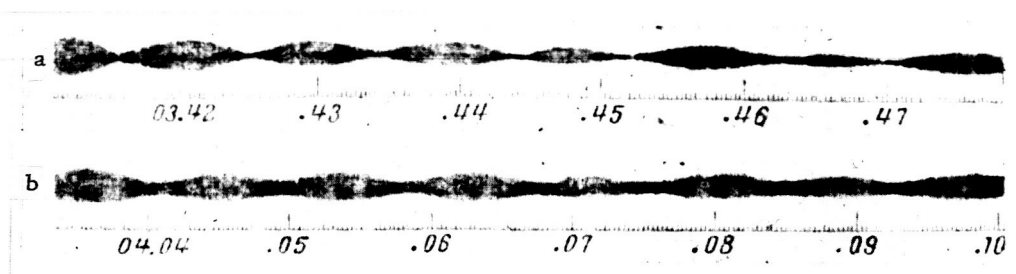


Fig. 6. Fading of radio signals from the 1st Soviet space rocket at 20 Mc (time pips, hour and minute)

a) 1-3-59 (250-cps band); b) 1-4-59 (100-cps band)

The latter phenomenon can be explained by the precession (together with the capsule) of the transmitting antenna whose radiation pattern was in the shape of a distorted tore. When the shape of an antenna radiation pattern is toroidal, signal fading is repeated twice during a revolution. This shows that the average periods of rotation of the capsules of the 1st and 2nd space rockets were 108 and 86 sec, respectively. The period of revolution of the capsule of the 3rd cosmic rocket, used for the photography of the dark side of the moon, was 165 sec. When photographs were to be taken a guidance system arrested the rotation of the capsule, whose period of rotation reached 180 sec after the completion of the photography.

The record of the 183.6-Mc signals from the 3rd Soviet cosmic rocket is shown in Fig. 7. It was obtained by means of a horizontally polarized dipole. When the above was compared to a record obtained by means of a vertically polarized dipole, the polarization maxima and minima, specified by the shape of the transmitting antenna pattern, were analyzed.

It can be seen from Fig. 7 that the polarization maxima appeared twice per revolution of the capsule, i.e., every 90 sec, while the minima, fixed by the antenna radiation pattern, appeared once, i.e., every 180 sec.

5. OBSERVATION OF THE FARADAY EFFECT

The presence of the Faraday effect, which caused the rotation of the plane of polarization of the incoming signals during their passage through the ionosphere, was distinctly observed at the frequency of 20 Mcs. Due to this effect, a reduction in the period of the polarized fading was observed at sunrise, when the concentration of ions along the propagation path of a signal is sharply altered.

Thus, for instance, the period of fading of the 20-Mc signals from the 1st Soviet space rocket was 40 sec at 7:50 on Jan. 3, 20 sec at 8:15, and 10 sec at 8:25.

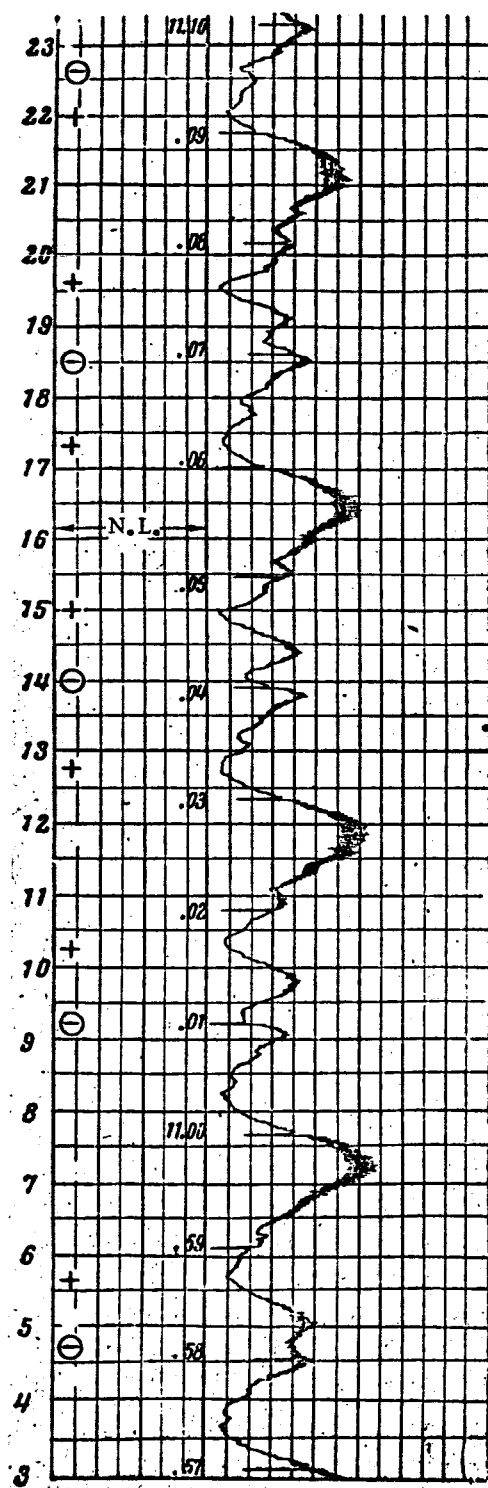


Fig. 7. Fading of radio signals from the 3rd Soviet space rocket at 183.6 Mc on 10-17-59.

+ denotes minima which have polarizing origins; \ominus denotes minima specified by transmitting antenna radiation pattern; N. L. -noise level

The gradual increase in the polarized fading due to the Faraday effect during the descent of the 2nd space capsule on September 13 can be seen in Fig. 8, where the hours and minutes appear near the vertical lines (the time constant of the automatic recorder was 5 sec). The period of fading was reduced as the thickness of the ionosphere decreased along the propagation path of the signal. The elevation of the capsule at 2:30 was approximately 8° .

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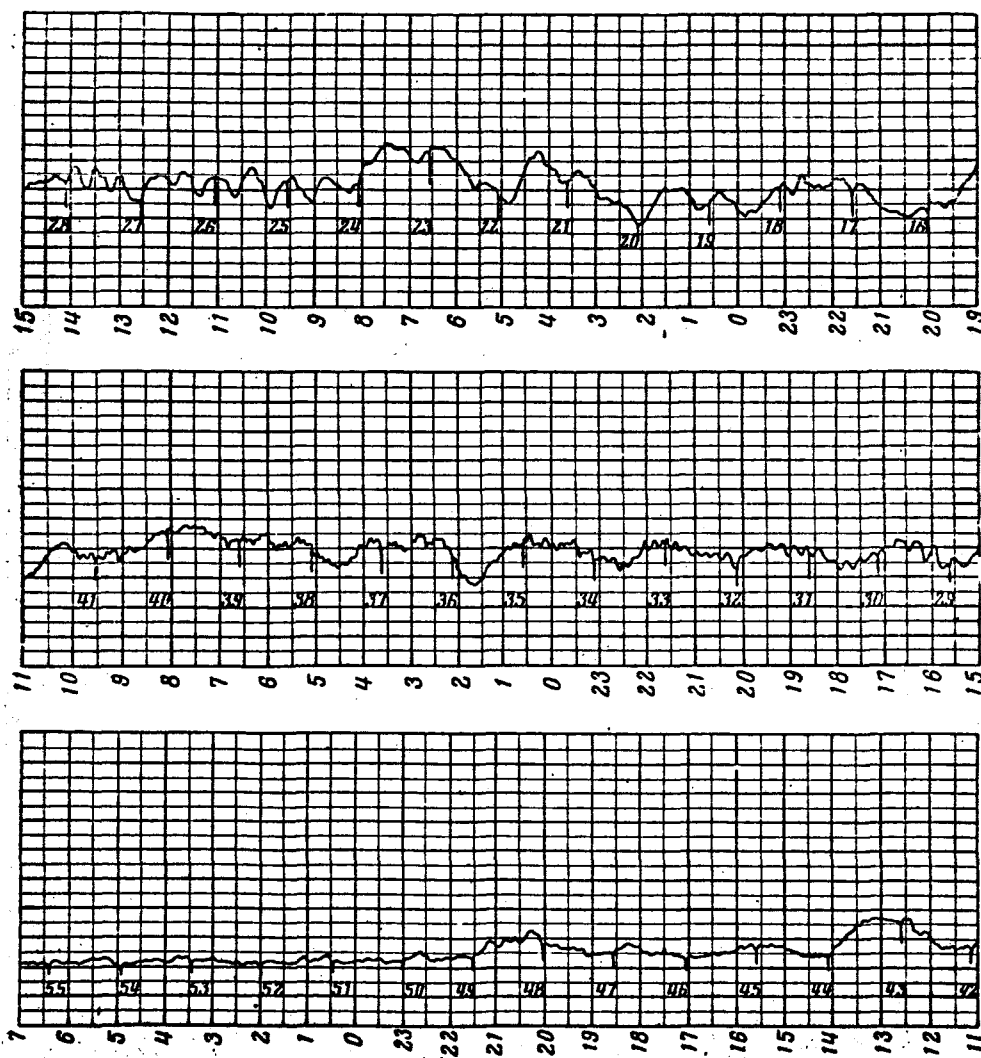


Fig. 8. Fading of radio signals from the 2nd Soviet space rocket at 20 Mc before capsule impact (Sept. 13, 1959)

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